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REPORT ON THE INSPECTION OF NEW JERSEY STATE HIGHWAY BRIDGES

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Inspection was made during the winter of 1958-59 of 44 bridges geographically situated in all sections of the state.

Thirty-nine of these bridges are known to be built between 1922 - 1934 and three between 1937 - 1940. The remaining two were believed to be built during the late twenties or early thirties.

All bridges have concrete slab decks. The great majority of them were covered with an asphaltic wearing surface.

Twenty-two of these bridges are definitely known to have structural steel beams or plate girders encased in concrete; one is a concrete rigid frame; one is a multiple concrete arch with approach spans of structural steel encased in concrete; one is a multiple span concrete T-beam; five are slab bridges; two are reinforced concrete beam bridges. The remaining twelve are beam bridges but could not be identified as structural steel encased in concrete or reinforced concrete.

Appendix A contains inspection notes on each bridge. For reference, bridges are given identification numbers.

Appendix B gives references on (a) damages to concrete, (b) recommendations for obtaining high quality concrete and (c) recommended design details and construction data for concrete bridges.

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Damage found in these bridges can be classified into the following groups:

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GROUP 1 - SEEPAGE

Water may permeate through the mortar through particles of aggregate or between mortar and aggregate. When seepage is in quantity, it is seen as a film of water and with rapid evaporation as crystalline deposits. When seepage is less it is evidenced by patches of efflorescence.

Open passageways for water are found in cracks, porosity of concrete and open joints in bridge decks. Inspections revealed crystalline deposits in practically all bridges inspected. Particularly, these deposits are on the underside of structural steel beams encased in concrete.

No one can be sure of the chemical contents of these crystalline deposits without laboratory investigation but they are believed to be salt solutions brought to the surface when the water evaporates. Tests have shown that these deposits leave a weakening effect upon the concrete. References in Appendix B will help to explain the nature of these deposits caused by seepage.

The harmful effects from seepage can be definitely minimized with high quality concrete and good design details.

To obtain same Section 2.4.5 of the A.A.S.H.O. Standard Specifications for Highway Bridges (1957) specifies that Class A (A E) concrete shall be used in all locations where the concrete will be exposed to severe or moderate natural weathering (alternate freezing and thawing) as well as concrete exposed to salt water action. In addition, the booklet, "Concrete Bridge Details" gives suggestions for design details and the booklet, "Design and Control of Concrete Mixtures" gives additional suggestions for obtaining high quality concrete. Both of these booklets are found in Appendix B.

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GROUP 2 - EROSION OF CONCRETE AT WATER'S EDGE

Eliminating the possibility of chemical attack from polluted water the damage, whether in salt or fresh water appears to be due less to action of water itself than to repeated action of frost where the concrete is alternately exposed to freezing temperatures between high and low water.

Examples of this damage are shown in the photos of Bridges Nos. 12, 14, 15, 16, 17, 21, 27, 29, 36, 37, 38, 39, 40 and 44. None were found to be serious.

Reference on the effect of salt water is found in the data sheet "Concrete in Sea Water" in Appendix B.

Erosion of concrete in water can be minimized with (a) high quality concrete and (b) control of pollution of Streams. Class A (AE) concrete in the A.A.S.H.O. bridge specification (Sec. 2.4.5) is recommended for this exposure. Additional suggestions are given in the booklet, "Design and Control of Concrete Mixtures" in Appendix B.

GROUP 3 - WEATHERING

This type of damage is common in areas subject to frost action. It is evidenced by cracks followed by deterioration on the surface of handrails, posts, tops of wing walls, ends of breast walls and piers which are exposed to the weather and vertical faces of exterior beams. Cracks are ordinarily close to and parallel to the edge and are usually filled with crystalline deposits.

Examples are found in the photographs of bridges Nos. 3, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 26, 28, 29, 31, 32, 35, 36, 37, 38, 39, 42, 43 and 44.

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Specimen of concrete in water can be minimized with (a)
(use A (AX) concrete in the A.A.S.H.O. bridge specification
(Spec. 6.4.1) is recommended for this purpose. Directions
for mixing are given in this booklet, "Design and Control of
Concrete Mixtures" in Appendix 7.

Specimens are usually cores. Cores are ordinarily close-
ly parallel to the axis and are usually filled with cement-

Frequently, cracking followed by deterioration found at the tops of piers, abutments and wing walls is traced to water gain at the time of concreting. This inferior concrete was unable to resist the cycles of freezing and thawing.

High quality concrete and care taken to handle and place the concrete will minimize the effects of weathering.

Section 2.4.5 of the A.A.S.H.O. bridge specifications specifies Class A (AE) in all locations where the concrete will be exposed to severe or moderate natural weathering. Class Y(AE) is specified for thin reinforced sections such as for handrails.

Section 2.4.10 of the A.A.S.H.O. bridge specifications specifies how the concrete is to be handled and placed.

Additional suggestions are given in the booklet "Design and Control of Concrete Mixture" in Appendix B.

GROUP 4 - WORKMANSHIP

Too dry a concrete causing honeycomb and rock pockets, overworking the concrete causing water gain on horizontal surfaces, carelessness in forming construction joints, and lack of curing produce damage to concrete.

Another damage is caused by the reinforcing steel being placed too close to the surface. Penetration of water reaches the reinforcing steel. Oxidation causes corrosion and expansion of the metal and results in the removal of the concrete cover.

Examples of exposed reinforcing steel are found in the photographs of Bridge Nos. 12, 16, 17, 24 and 43.

specifies Class F (SF) in all locations where the concrete will be exposed to severe or moderate natural weathering.

Additional explanations are given in the booklet "Design and Control of Concrete Mixtures" in Appendix 1.

Section 1.7.5 (b) of the A.A.S.H.O. Standard Specifications for Highway Bridges specifies that "the minimum covering measured from the surface of the concrete to the face of any reinforcement bar shall not be less than 2 inches - - - - - -".

Additional suggestions on recommended concrete protection over reinforcement is found in the data sheet, "Architectural Concrete Specifications" Appendix B.

GROUP 5 - DESIGN AND DETAILS

Good design and details can minimize damages from (a) poor drainage of the roadway and in the backs of walls; (b) insufficient number of contraction joints in walls; (c) improper location of pipe lines and (d) errors in design assumptions that lead to insufficient reinforcement to resist the stresses.

A great many bridges showed evidence of drainage from the roadway through the deck slabs and deck joints accompanied by crystalline deposits as discussed under Group I - Seepage. It is suspected the water carried with it solutions of calcium choride that was applied to an icy deck.

Bridge Nos. 16 and 17 are examples where concrete deterioration was caused by cycles of freezing and thawing of water (with possible salt solutions) that was draining from the roadway.

Bridge Nos. 1 and 18 are examples of poor drainage in back of walls.

Vertical cracks in many breast walls are believed to have resulted from lack of sufficient shrinkage control joints. Shrinkage may be non-uniform because the front surface being

exposed dries out in relation to the rear surface that is kept moist by the adjacent fill. The shrinkage tends to set up tensile stresses in the breast wall.

Bridge No. 17 is an example of concrete deterioration caused by a pipe line at the water table.

Joint action between breast wall and wing walls is difficult to analyze, and the safe and economical amount of reinforcement can seldom be calculated. Cracks may develop in wing walls and at the junction of wing wall with breast wall. Possible examples are found in Bridges Nos. 8, 14, 16, 17, 33 and 44.

In addition, vertical cracks can be created in breast walls because of the lack of adquate reinforcement.

Vertical cracks were found in the breastwalls of Bridge Nos. 5, 7, 24, 27 and 42. From inspection there is no assurance that all of these cracks can be attibuted to lack of reinforcing steel, but the possibility remains that some of the walls are so affected.

A detailed discussion on causes of structural cracks in walls and provisions for minimizing them are found in the booklet, "Concrete Bridge Details" in Appendix B. The booklet also gives suggestions for details on drainage, wall and deck joints.

GROUP 6 - DISPLACEMENTS

This type of damage results from settlement of footings, expansion and contraction, and lateral creep of the deck.

Bridges Nos. 1 and 34 are examples of settlement of footings.

Bridges Nos. 28 and 34 are examples of deck creep movement.

In skew bridges the longer diagonal of the deck has a tendency to lengthen during a long period of service.

The causes of creep and methods of preventing it are discussed in the booklet, "Concrete Bridge Details" in Appendix B.

GROUP 7 - AGGREGATE PERFORMANCE

Experience has shown that the damaging influence of aggregates on concrete durability has been caused by, (a) chemical decomposition, (b) freezing of water in the aggregate pores; (c) differential expansion between mortar and aggregate; and (d) reaction between the cement and aggregate known as alkali-aggregate reaction.

No attempt is made in this report to identify the type of damage associated with aggregate performance.

There is a possibility this type of damage is associated with the groups of damages discussed elsewhere in this report.

Further investigation of Bridges Nos. 14, 16, 17, 26, 35 and 37 may reveal damages caused by aggregate performance.

However, only petrographic, chemical and other recognized methods should be used for this investigation.

examples of deck creep move-

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Appendix B.

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and (f) reaction between the cement and aggregate

report to identify the type

This is a possible fair type of damage is associated

damage discovered during inspection.

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APPENDIX A

BRIDGE NO. 1

Route U.S. 1 - Magnolia Street - Elizabeth

Built - 1934

Spans - Six

Type - Structural Steel encased in concrete

Condition - West abutment has settled causing horizontal cracks. Abutments and approach retaining walls cracked. Poor drainage. Considerable crystalline deposits on concrete faces. See photos.

BRIDGE NO. 1

BRIDGE NO. 2

Route U.S. 1 - Overpass at Newark Circle - Newark Junction

Built - ?

Spans - Four

Type - Structural steel encased in concrete

Condition - Same disintegration of the concrete cover over the structural steel. Crystalline deposits on the concrete cover. Photo shows leeching and disintegration at east abutment. Piers in good condition. Repairs have been made on balustrade and at the water table at the base of balustrade.

BRIDGE NO. 3

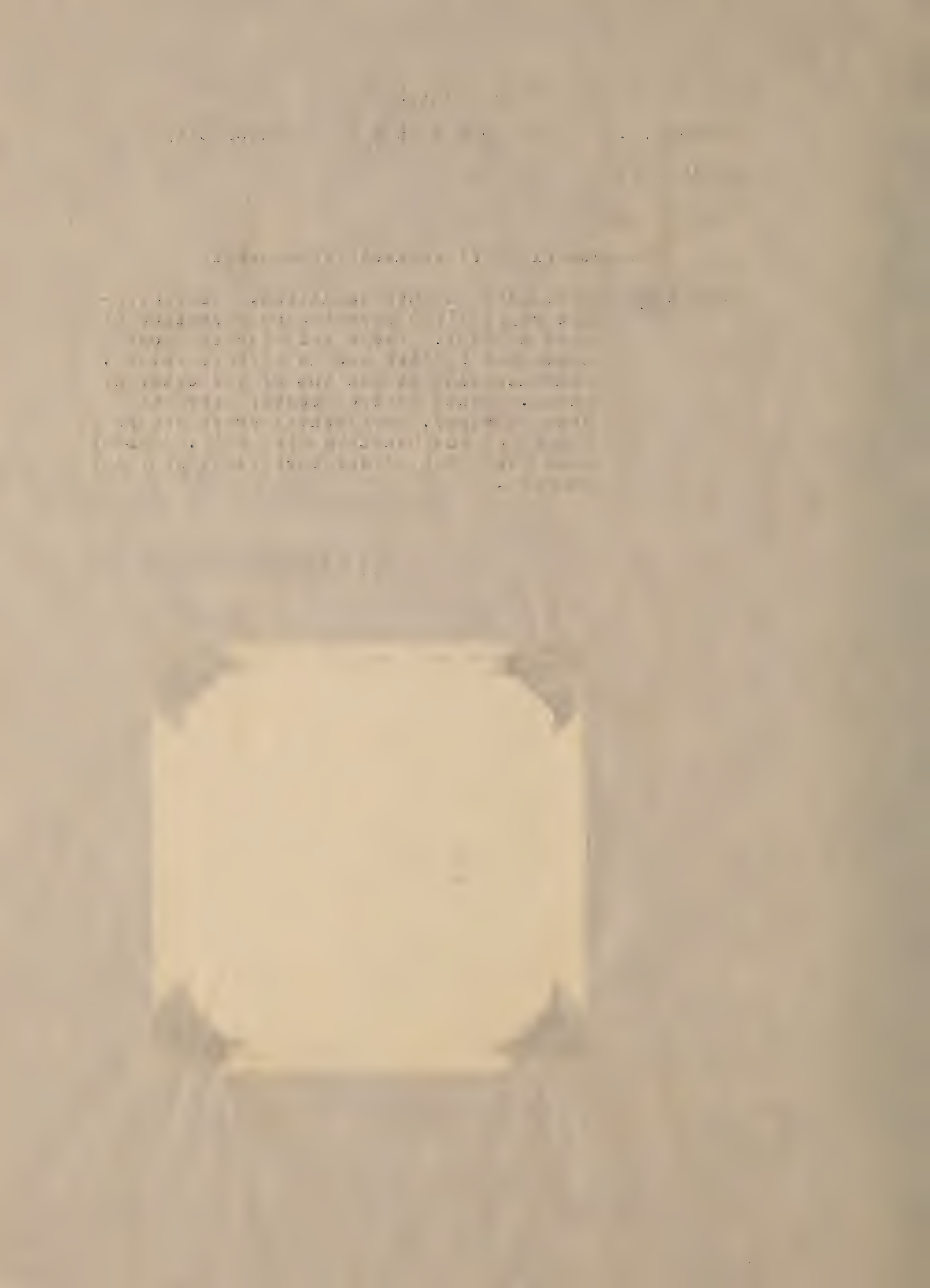
Route U.S. 3 - NYS & W & No R R - Union City

Built - 1929

Spans - Four

Type - Structural steel encased in concrete

Condition - Abutments in good condition. Considerable crystalline deposits on underside of bridge beams. Piers are cracked, concrete has spalled and is disintegrating. Some leeching at the top of the exterior beams. South face of center pier has been repaired. Horizontal crack occurs at coping of southwestern wing wall. Photos show piers and girder encasement near the support.



BRIDGE NO. 3

BRIDGE NO. 4

Route 4 - Hackensack River - West Englewood

Built - 1931

Spans - eight

Type - Structural steel plate girders encased in concrete

Condition - No apparent damage.
No photos taken.

BRIDGE NO. 5

Route 4 - Margaret Street - Teaneck

Built - 1931

Spans - One

Type - Half-thru structural steel plate girder encased in concrete

Condition - Some vertical cracking in abutment walls. No disintegration of concrete anywhere. Some vertical cracks in abutments. Photo shows crystalline deposits at vertical crack at rustications east bound side.

BRIDGE NO. 6

Route 4 - Queen Anne Road - Teaneck

Built - 1931

Spans - One

Type - Structural steel encased in concrete

Condition - Some shrinkage, cracks on face of abutment - not serious. One exterior girder on all sides, the concrete cover is disintegrating. Concrete shows poor workmanship that is indicated by high slump and cold joints. No photos taken.

BRIDGE NO. 7

Route 4 - Garrison Avenue - West Englewood

Built - 1931

Spans - One

Type - Half-thru structural steel plate girder encased in concrete.

Condition - Some vertical cracks in the abutment walls where change of mass occurs. One intermediate vertical crack between expansion joints on abutments. Under one bearing on west bound wall concrete has been loosened and removed. Structure is in sound condition generally. No photos taken.

BRIDGE NO. 8

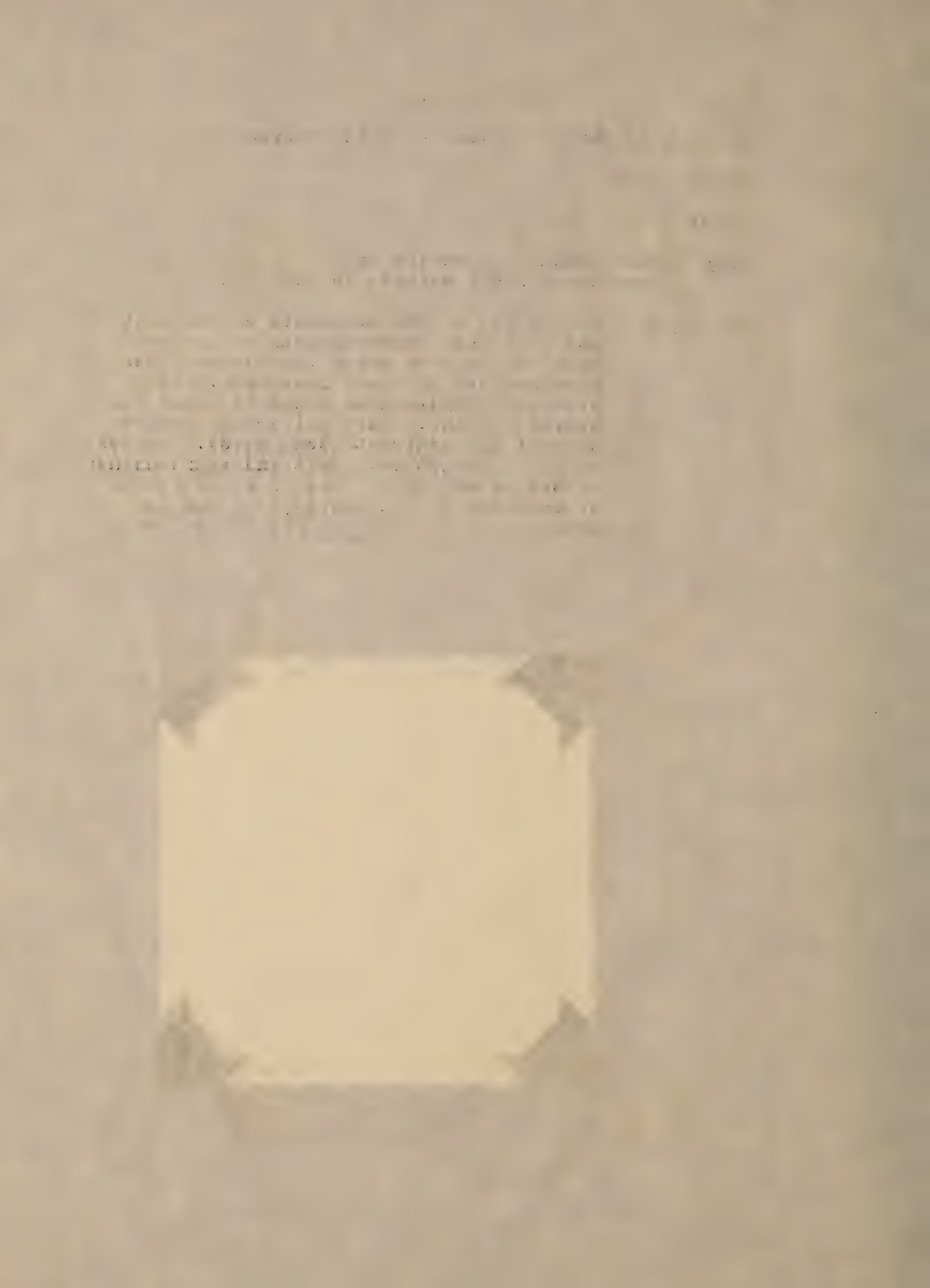
Route 4 - Passaic River - East Paterson

Built - 1931

Spans - Multiple

Type - Open spandrel concrete arch. Approach spans structural steel encased in concrete.

Condition - At the top of the abutments on the west end, vertical cracks appear at the bearings and in some areas the concrete has sloughed off at these locations. Considerable crystalline deposits under the approach spans. Vertical crack appears on west end abutment (see photo). Arches in sound condition. East end approach not as bad as west end. Some disintegration of concrete at the bearings on the east abutment.



BRIDGE NO. 8

BRIDGE NO. 9

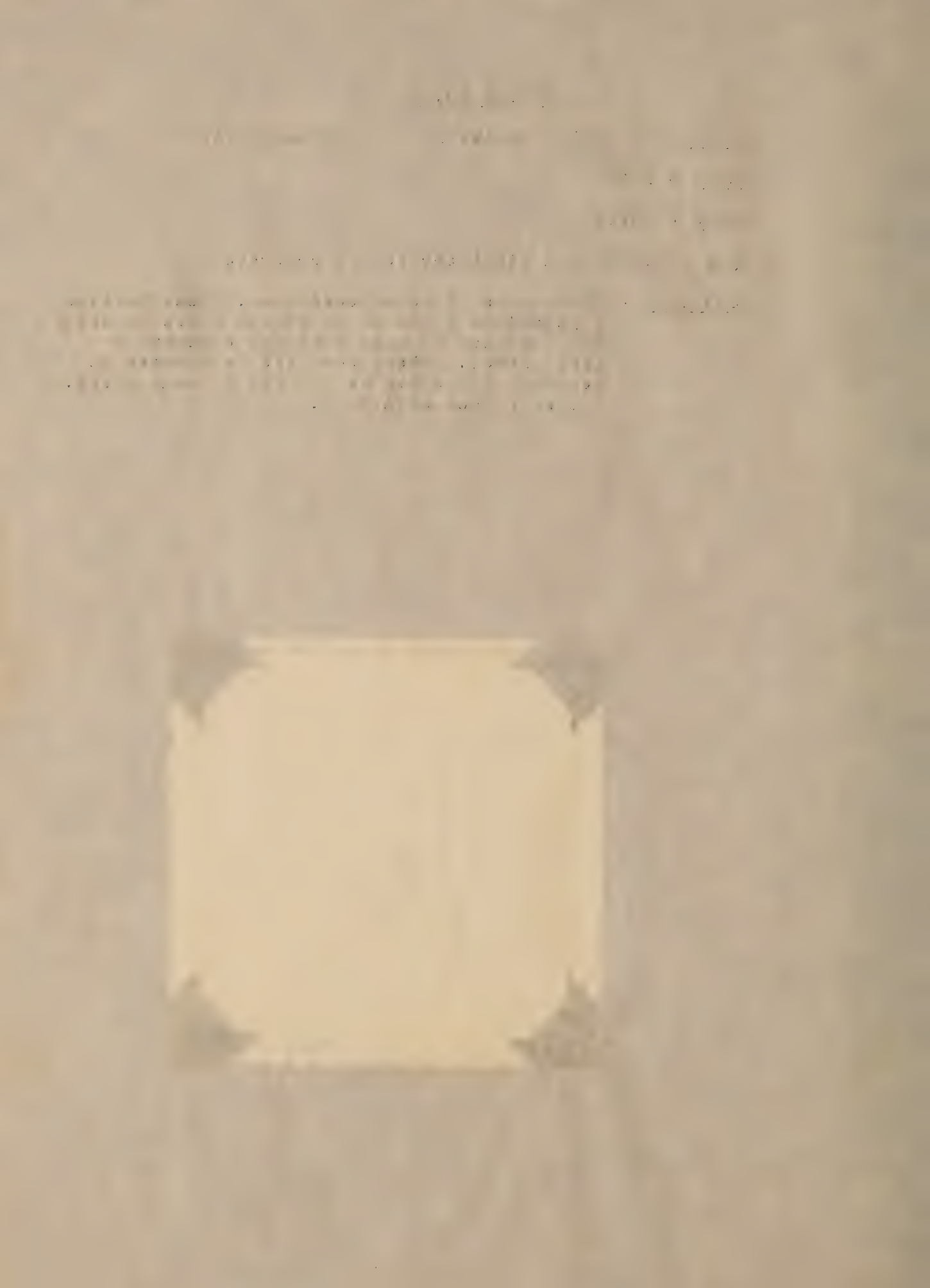
Route 5 - Delia Boulevard - Cliffside Park

Built - 1924

Spans - Three

Type - Structural steel encased in concrete

Condition - Abutments in sound condition. Considerable crystalline deposits on soffit sides of beams and junction of slab with the concrete cover (see photo). Where concrete is exposed to weather, aggregate is exposed in some areas. Piers in good condition.



BRIDGE NO. 10

Public Service Railroad - Cliffside Park

Built - 1924

Spans - Three on skew

Type - Concrete slab

Condition - Wing walls and retaining walls in sound condition. A few rock pockets in piers. Some broken concrete at top of one pier at one location (see photo). Crystalline deposits on some areas at the junction of the slabs with piers (see photos).

BRIDGE NO. 11

Route 9 - Jobs Creek - New Gretna

Built - 1922

Spans - One

Type - Beam

Condition - Repairs have been made on faces of exterior beams. On upstream side, the concrete cover has come off the bottom longitudinal steel on the exterior girder at both ends. Timber supports are under the girder at one end. See photos.

BRIDGE NO. 12

Route 9 - West Conk Creek - West Creek

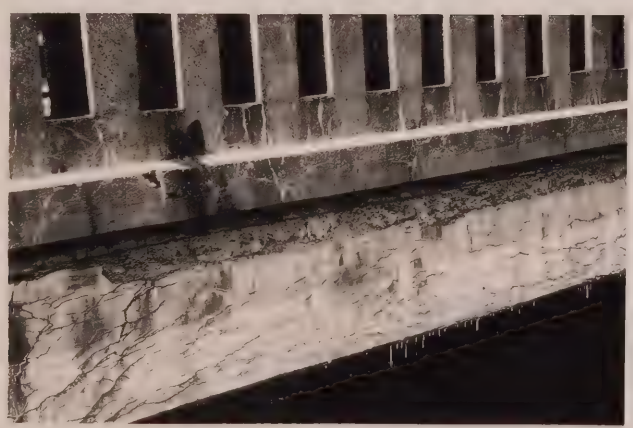
Built - 1925

Spans - Two

Type - Beam

Condition - Concrete cover has come off the bottom reinforcing steel on one exterior girder. Disintegration of concrete on top of balustrade post. Crystalline deposits on face of exterior beams. See photos.

BRIDGE NO. 12



BRIDGE NO. 13

Route 9 - Mill Creek - Manahawkin

Built - 1925

Span - One

Type - Beam Bridge

Condition - North wing walls in sound condition. Coping on south end wing walls badly disintegrated. Balustrades in good condition. Curb on upstream face disintegrated on south end. Upstream exterior girder shows some vertical cracking. abutments in sound condition. See photos.

BRIDGE NO. 13

BRIDGE NO. 14

Route 9 - Waretown Creek - Waretown

Built - 1925

Spans - Two

Type - Concrete slab

Condition - On pier on west side the coping and vertical edge the concrete has disintegrated. On pier on upstream side the concrete has disintegrated at the top surface. Some surface cracking on the southeast wing wall. One vertical crack is seen on northeast wing wall. Wing walls on west side are in good condition. Cracking accompanied by crystalline deposits are seen in the vertical exposed sides of the slab. See photos.

BRIDGE NO. 15

Route 9 - Oyster Creek - Waretown

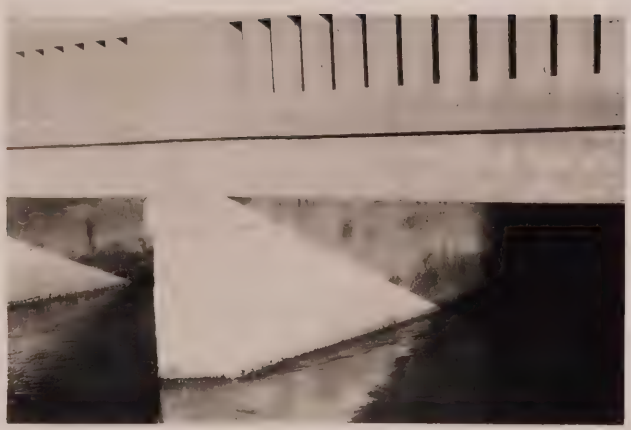
Built - 1925

Spans - Two

Type - Slab

Condition - Concrete on pier on upstream face disintegrated. Coping on the abutment and coping on wing wall both at northwest corner have disintegrated. Cracking accompanied by crystalline deposits are prevalent throughout. On the balustrades reinforcing bars are exposed. Concrete is etched at the water level. See photos.

BRIDGE NO. 15



BRIDGE NO. 16

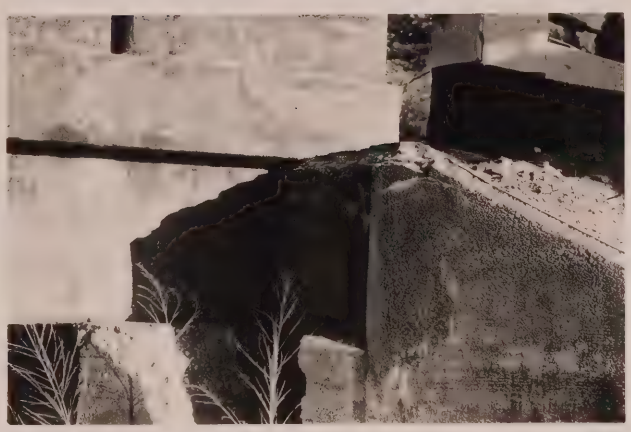
Route 9 - So. Branch Forked River - Forked River

Built - 1928

Spans - Two

Type - Slab

Conditinn - Pier tops on both sides of the bridge disintegrated coping on wing wall on southeast corner disintegrated. Large horizontal and vertical cracking on northeast wing wall. All vertical surface badly cracked accompanied by crystalline deposits. Concrete is etched at the water level. See photos.



BRIDGE NO. 16

BRIDGE NO. 17

Route 9 - Middle Branch Forked River - Forked River

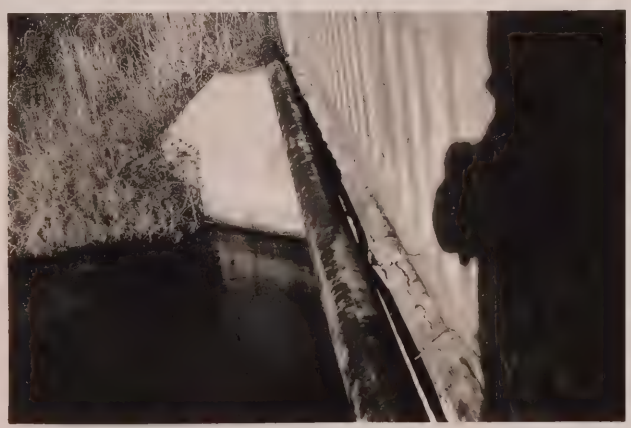
Built - 1925

Span - One

Type - Beam

Condition - Water table under the pipe line on the upstream face disintegrated. Reinforcing steel seen exposed on vertical side of exterior beams. Vertical cracking on wing wall at southwest corner and at this location the horizontal surface of the wing wall adjacent to the bridge is disintegrated. Considerable crystalline deposits on sides of exterior beams. Concrete is etched at water's edge.

BRIDGE NO. 17



BRIDGE NO. 18

Route 35 - Route 36 Overpass - Keyport

Built - North span 1931 - South span later

Spans - Two

Type - Structural steel beams encased in concrete

Condition - Concrete chipped away at bearings. Many cracks in face of north abutment accompanied by crystalline deposits. Poor drainage. See photo. Center pier and south abutment in sound condition.

BRIDGE NO. 18

BRIDGE NO. 19

Route 35 - Cheesequake Creek - Morgan

Built - 1942

Spans - Nine

Type - Structural steel encased in concrete and two exposed structural steel bascule spans.

Condition - On south abutment the concrete was chipped away at the bearings. Crystalline deposits seen on vertical faces of piers. See photo. Structure is in good condition.

BRIDGE NO. 20

Route 37 - Union Branch - Lakehurst

Built - 1934

Spans - One

Type - Beam

Condition - Upstream and downstream faces in good condition. Parts of the top of balustrade on both sides disintegrated. See photo.

BRIDGE NO. 21

Route 37 - Toms River - Toms River

Built - 1928

Spans - Two on skew

Type - Thru structural steel plate girder encased in concrete

Condition - At the northwest corner at the abutment there is seen evidence of a movement (see photo). Except for some minor disintegration at the base of the balustrade posts and some water leakage at the abutments underneath the bridge is in good condition. Crystalline deposits are seen on the piers and deck.

BRIDGE NO. 22

Route 46 - D.L.&W.R.R.&Rockaway River - Rockaway

Built - 1928

Spans - Multiple

Type - Reinforced concrete T-beams

Condition - Copings at top of piers disintegrated. In some locations the concrete at base of columns has disintegrated. Coping on one wing wall completely disintegrated. Side walk, used to store cinders and calcium chloride, completely disintegrated. Exposed reinforcing steel on underside of slab and in a few beams. Extensive repairs have been made on bottom of deck. Vertical faces of piers at river, both upstream and downstream, show signs of disintegration. Large areas of vertical surfaces covered with crystalline deposits. See photos.

BRIDGE NO. 22

BRIDGE NO. 23

Route 46 - Center Avenue - Fort Lee

Built - 1930

Spans - Two

Type - Structural steel encased in concrete

Condition - Concrete cover removed from the soffit of steel beams in some areas. Concrete at top of abutments disintegrated at the ends of the pier. There is disintegration at coping level. Photos show pier and west side.

BRIDGE NO. 24

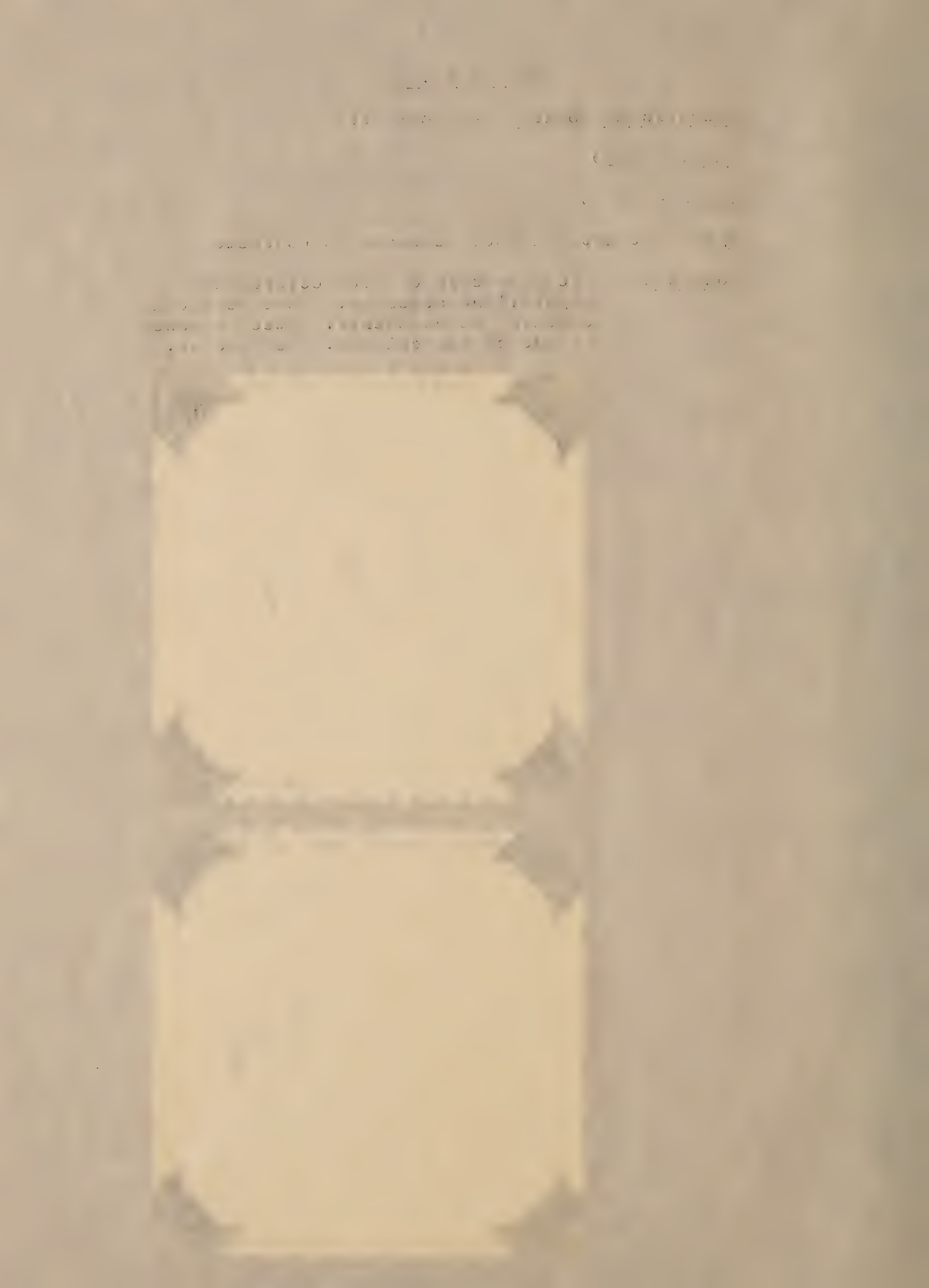
Overpass at Route 4 - Fort Lee

Built - 1930

Spans - Eight

Type - Structural steel encased in concrete

Condition - The underside of deck covered with crystalline deposits. Some vertical cracking at abutments. Steel exposed in one of the columns. See photos.



BRIDGE NO. 25

Edwin Avenue - Fort Lee

Built - 1930 or 1931

Spans - One

Type - Half-thru structural steel plate girder encased in concrete

Condition - Wing walls and abutments in sound condition. No evidence of concrete disintegration. Some minor crystalline deposits on underside of concrete cover. No photos.

BRIDGE NO. 26

Route 49 - Penn-Reading S. S. Lines R. R. - Tuckahoe

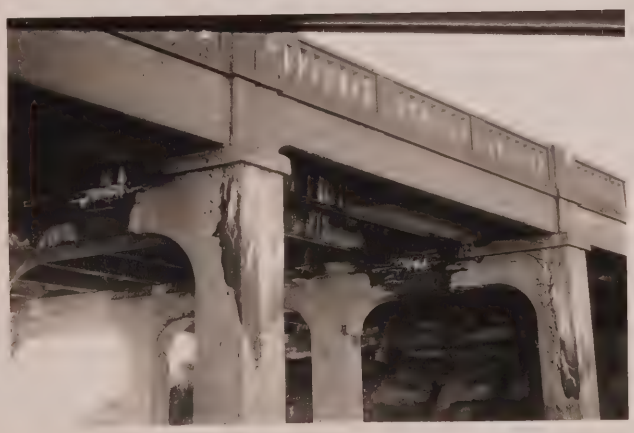
Built - 1930

Spans - Five

Type - Structural steel encased ?

Condition - Piers cracked. Crystalline deposits through cracks and on underside of deck. See photos.

BRIDGE NO. 26



BRIDGE NO. 27

Route 50 - Great Egg Harbor River - Mays Landing

Built - 1928

Span - One

Type - Structural steel plate girder encased in concrete

Condition - Large vertical crack in center of west abutment. Some slight cracking on surface. Concrete is etched at water's edge. Bridge in good condition. See photo.

BRIDGE NO. 28

Route 50 - Penn.-Reading R. R. - Petersburg

Built - 1925

Spans - Five (Skew)

Type - Structural steel encased in concrete

Condition - Lateral movement of the span over the tracks on the north side. Balustrade apparently not the original. Cracking of concrete surface of piers and concrete cover accompanied by considerable crystalline deposits. Signs of water seepage from deck to piers and abutments. See photos.

BRIDGE NO. 28

BRIDGE NO. 29

Route 50 - South River - Mays Landing

Built - 1927

Spans - One

Type - Beam

Condition - Coping on abutment on upstream side disintegrated. Exterior girders on both sides cracked accompanied by crystalline deposits. See photo.

BRIDGE NO. 30

Route 69 - South Branch Raritan River - Flemington

Built - 1928

Spans - Three

Type - Thru structural steel plate girder encased in concrete.

Condition - Vertical crack in one of the piers. Piers and north abutment have been repaired. South abutment wing wall deteriorated in spots. Crystalline deposits on abutment walls. See photo.

BRIDGE NO. 31

Route 70 - Penna. Railroad - Upton

Built - 1932

Spans - Five

Type - Structural steel encased in concrete

Condition - Considerable cracking on vertical surfaces accompanied with crystalline deposits. Some disintegration at the water table at base of the deck. Crystalline deposits on the underside of deck. See photos.

BRIDGE NO. 31

BRIDGE NO. 32

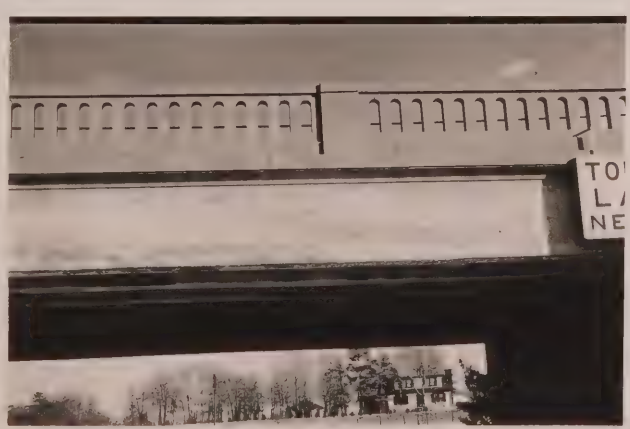
Route 9 and Route 70 - Lakewood

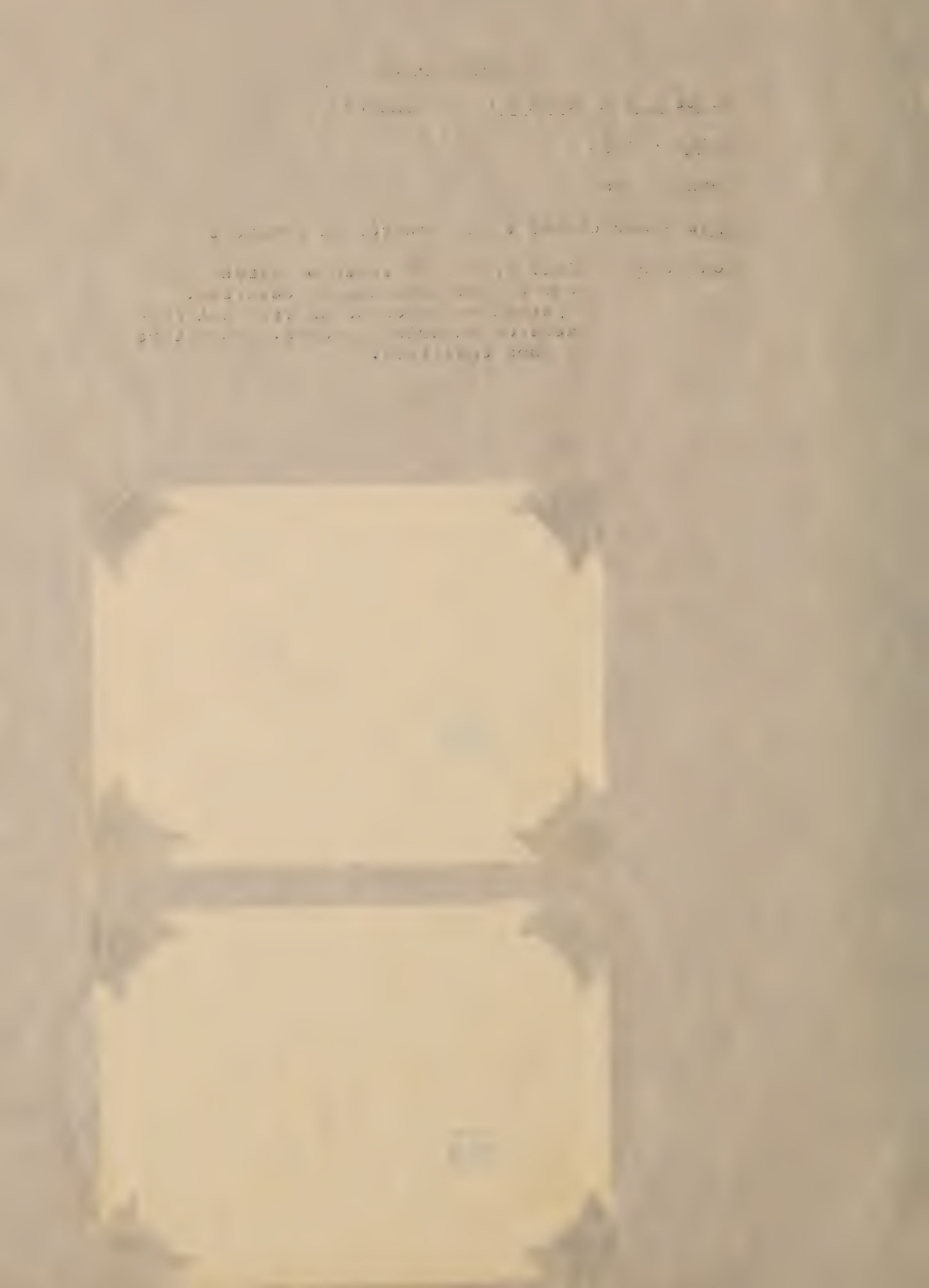
Built - 1936

Spans - Two

Type - Structural steel encased in concrete

Condition - Minor cracks in exterior girder and some slight spalling of concrete. Crystalline deposits on vertical surfaces of exterior girders. Structure in good condition.





BRIDGE NO. 33

Route 72 - Mill Creek - Manahawkin

Built - 1930

Spans - One

Type - Beam

Condition - Horizontal crack in southeast wing wall. Crystalline deposits on upstream exterior girder. Bridge is in good condition. See photos.

BRIDGE NO. 34

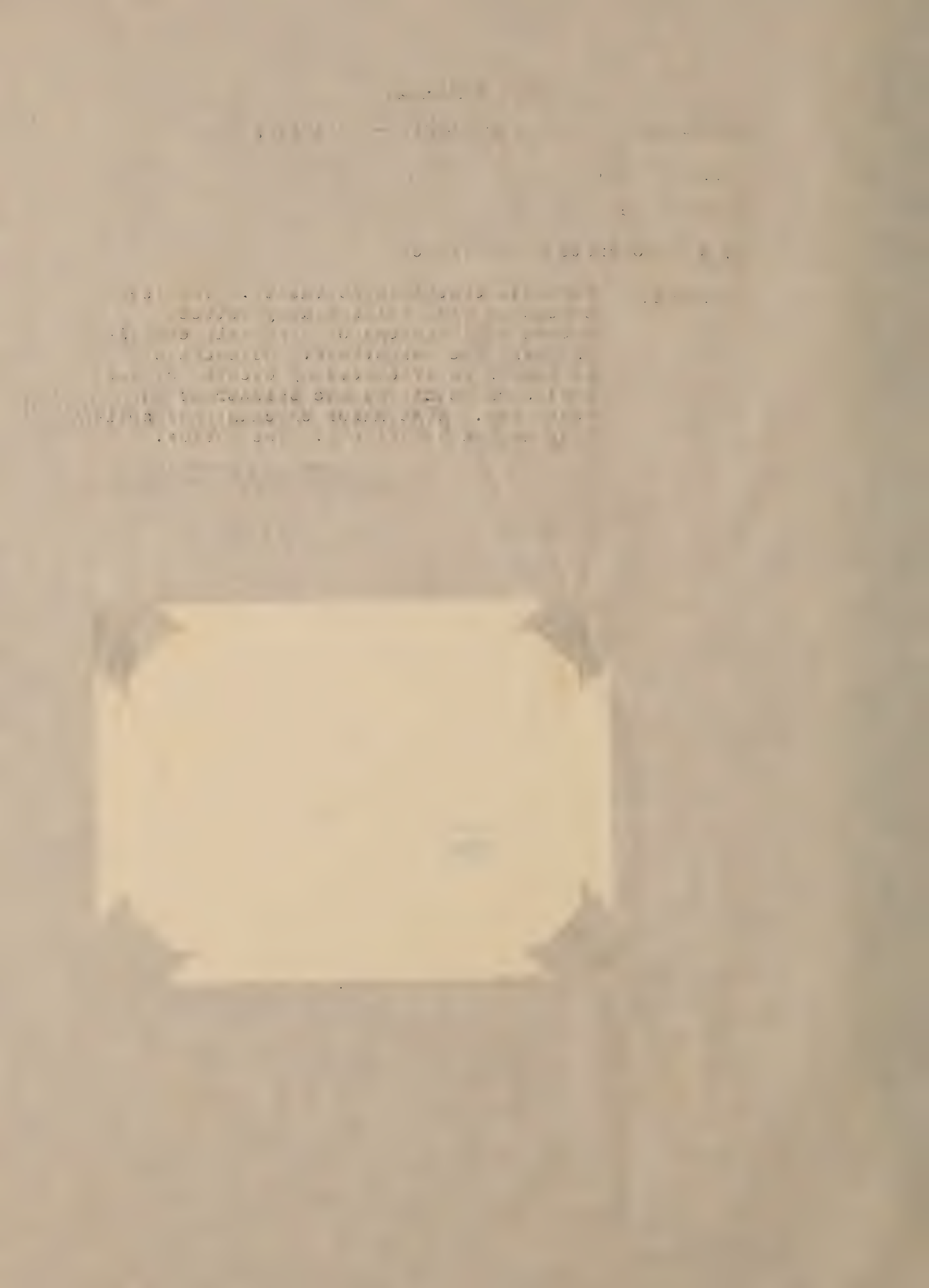
Route 130 - Brainard Lake - Cranbury

Built - 1937

Span - One

Type - Concrete rigid frame

Condition - Vertical cracks in abutments. Vertical cracks in wing walls midway between breast wall and end of wing wall extending thru the balustrade. Movement of abutments as evidenced by opening of the expansion joints in the balustrade on south end. Some minor cracking and spalling in the balustrade. See photos.



BRIDGE NO. 34

BRIDGE NO. 35

Route 159 - Passaic River - Pine Brook

Built - One side 1940 - other side older

Spans - Four

Type - Part thru-structural steel girder encased in concrete

Condition - The bridge has been widened. A different balustrade has been placed on one side which is dated 1940. The downstream face of the bridge in good condition. Concrete at top of the piers and cover over the bottom flange of the girders is disintegrated. See photo.

BRIDGE NO. 36

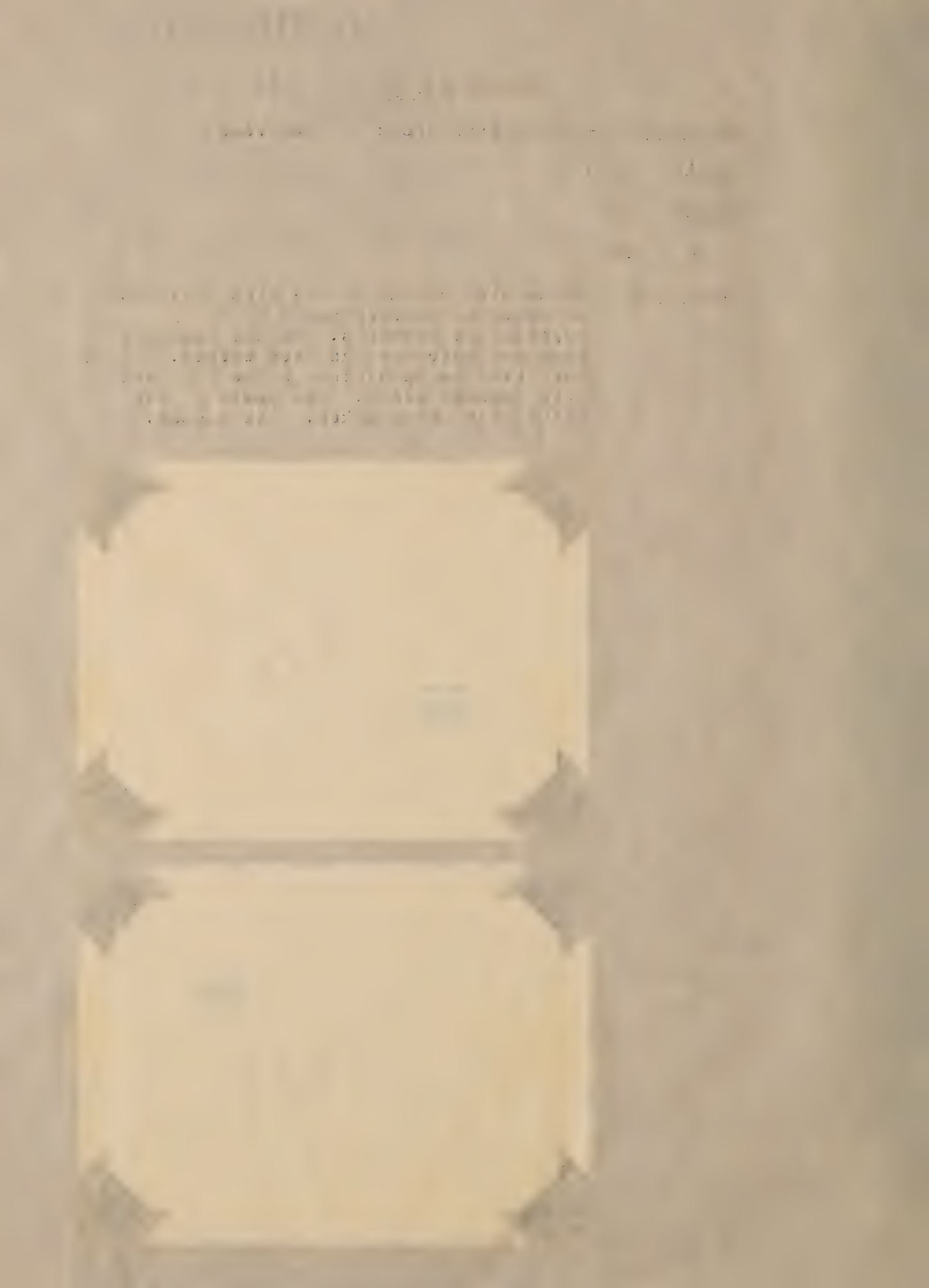
Route 206 - Albertson Brook - Rockwood

Built - 1930

Spans - One

Type - Beam

Condition - Horizontal cracks on the side elevation of exterior girders accompanied by crystalline deposits. On the upstream face the concrete has been etched. Where the water table overhangs the wing wall rock pockets occur. End posts of the balustrade are cracked. See photos.



BRIDGE NO. 37

Route 206 - Clarks Brook - Rockwood

Built - 1930

Spans - One

Type - Beam

Condition - Wing wall coping at northeast corner disintegrated. All end posts of balustrade badly cracked. Wing wall on upstream face etched. Horizontal cracks at midheight of exterior girders accompanied by crystalline deposits.

BRIDGE NO. 37

BRIDGE NO. 38

Route 206 - Sleepers Brook - Rockwood

Built - 1930

Spans - One

Type - Beam

Condition - The structure is in about the same condition as the one at Clarks Brook, Rockwood. The etching in the upstream face is not as pronounced. See photos.

BRIDGE NO. 39

Route 206 - Springer Brook - Indian Mills

Built - 1929

Spans - Three

Type - Beam

Condition - With the exception of some minor cracking, the structure is in sound condition. Some patch work has been done on the balustrades. See photos.

BRIDGE NO. 39

BRIDGE NO. 40

Route 206 - Br. So. Branch Rancocas Creek - Red Lion

Built - ?

Span - One

Type - Beam

Condition - Etching of concrete at high water line. Crystalline deposits on all exposed surfaces. See photos.

BRIDGE NO. 40

BRIDGE NO. 41

Route 206 - Br. So. Branch Raritan River - Bartley

Built - 1928

Span - One

Type - Slab

Condition - Underside of slab in good condition. Downstream south side wing wall cracked, probably due to movement. Otherwise, no damage visible. No photos.

BRIDGE NO. 42

Route 206 - Big Flat Brook - Sandyston

Built - 1929

Span - Two - Skewed

Type - Beam

Condition - One vertical crack in pier and in both abutments. Top of post on balustrade on downstream side disintegrated. Exterior girders on downstream side cracked with some spalling. Disintegration of concrete at coping level of one abutment on downstream side. Crystalline deposits on underside of deck and side elevations of bridge. Upstream side of structure in good condition. See photos.

BRIDGE NO. 42

BRIDGE NO. 43

Route 322 - Penn-Reading Railroad - Folsom

Built - 1931

Spans - Five

Type - Structural steel encased in concrete

Condition - Balustrade in fairly good condition; cracks at posts and some reinforcing steel exposed. Signs of water seepage thru deck at junction of slab with stem accompanied by crystalline deposits. Some cracks near top of piers. Wing walls cracked at top. See photo.

APPENDIX B

PARTIAL LIST OF REFERENCES

FROM AMERICAN CONCRETE

INSTITUTE JOURNALS

1 - Maintenance and Repair of Bridges - C. B. McCullough
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2 - The Durability of Concrete in Service - F. H. Jackson
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3 - Cement - Aggregate Reaction in Concrete - Duncan, McConnell, Richard
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4 - Concrete Deterioration in a Shipway - Ruth D. Terzaghi
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5 - Leaching of Lime From Concrete - Katharine Mather
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6 - Leaching of Lime From Concrete - C. T. Wolley
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7 - Durability - May 1952
(a) Railway Concrete - C. B. Porter
(b) Railway Concrete Deterioration - R. W. Gilmore
(c) Durable Concrete in Hydraulic Structure - Lewis H. Tuthill
(d) Durability of Hydraulic Structures - B. W. Steele

8 - Erosion Resistance of Concrete in Hydraulic Structures
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9 - Maintenance and Repair of Concrete Bridges on the Oregon Highway System - G. S. Paxson-November 1945

10 - Basis for Classifying Deleterious Characteristics of Concrete Aggregate Materials - E. G. Swenson and V. Chooly - May 1956

REFERENCES FROM HOOL AND JOHNSON'S

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1 - Efflorescense - Page 67

2 - Harmful Effects of Voids Caused by Excess Water - Page 34

3 - Excess Water The Cause of Day's Work Planes - Page 34

4 - Shrinkage Cracks - Page 84

5 - Shrinkage Cracks and Porosity - Page 84

6 - Effect of Temperature and Atmospheric Effects On Water - Tightness - Page 86

REFERENCES FROM TRAUTWINE'S

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1 - Free lime, slacked lime, quick lime and free magnesia - page 947e

2 - Effect of Sea Water - Page 947

PORTLAND CEMENT ASSOCIATION

PUBLICATIONS (Contained in Separate Binder)

1 - Notes on Efflorescence

2 - Concrete in Sea Water

3 - Effect of Various Substances on Concrete and Protective Treatments Where Required.

4 - Effect of Aggregate Characteristics in Quality of Concrete

5 - Tests of Concrete Containing Air-Entraining Portland Cements or Air-Entraining Materials

6 - Basic Principles of Air-Entrained Concrete

7 - Concrete Bridge Details

8 - Continuous Concrete Bridges

9 - Expansion Joints in Concrete Bridge Decks and Retaining Walls

10 - Watertight Concrete

11 - Prevention of Plastic Cracking in Concrete

12 - Volume Changes In Concrete

13 - Architectural Concrete Specification

14 - Construction Joints

15 - Forms for Architectural Concrete

16 - Observations on the Resistance of Concrete to Freezing and Thawing

17 - Concrete Aggregates - Chemical Reactions

18 - Resistance to Weathering - Freezing and Thawing

19 - Design and Control of Concrete Mixtures

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